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Analysis of Energy Efficient Thermoelectric Energy Harvesters for Powering of Low Power Devices

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Abstract

In present work analysis of energy efficient thermoelectric energy harvesters for powering of low power devices has been proposed. Today's scenario is to design and develop low powered and highly efficient self-powered devices for energy harvesting. Due to the abundant amount of availability of thermal energy from various sources, the area is open up to use for various applications and it needs to apply proper energy generators. For implementation of energy harvesting thermoelectric micro generators, commercially available CMOS process is mostly employed. To increase power, numbers of thermocouples are connected in series. For significance of power improvement temperature gradient should be taken in to consideration. Use of different low dimension materials makes impact on Seeback coefficient.

Keywords: Energy harvesting, Thermoelectric, Seeback coefficient

INTRODUCTION

Now a day's price of petrol and diesel are increasing with a rapid rate and it threats a lot more in future. Not only petrol and diesel, but it is the same case with even electricity too. Due to scarity of water and coal, production of electricity is highly affected which results in the use of electric instruments and equipment's in a limited manner. Simply it means that the natural energy sources are going to die out very soon in the next few years and will not be perhaps available for our next generations if proper care is not taken into account.

Use of fossil fuels is therefore making it to think twice before using it for any cause. Hence the best alternative option is to go for non-renewable energy sources like solar energy, wind energy, waste heat energy, mechanical vibrations which are available in huge amount in all time with free of cost. In future, therefore the conversion of these non-renewable energy sources into electrical energy is the major thrust. One way of this process is to design a proper energy generator now become vital. Use of solar energy through photo voltaic is now popular worldwide for a variety of applications. Hybrid systems with both solar and wind are also launched successfully. Wind and solar energy harvesters have some limitations as both are not available for 24 hours. And for solar efficiency is the major concern as the research is going on to increase the efficiency of solar panels.

There is still one source which is not utilized as much as it is available in a massive amount is a thermal energy which is waste heat energy everywhere in all respects.

The places like kitchen, exhaust of chimneys in industries. But still and waste heat from vehicles etc. are the main sources of thermal energy for energy harvesting. In recent years plenty of research work is done already in this area. But still some rears and tears are there like storage of energy, and low voltage and current and low power output are the main issues. Besides these limitations, these thermal energy generators can be used for powering low power devices such as smart phones, cardiac pacemakers and similar kind of applications. This can even avoid the use of batteries to increase the life of low power devices. In proposing work real focus is on the designing of thermo-electric generators (TEG).

The basis behind all this is the Seebeck and Peltier effects. Which forces to make use of thermocouples and thermopiles for conversion of heat energy into electrical energy. There are plenty of methods employed for designing of efficient TEG'S. But the most popular one is CMOS technology. Now a days with the invention of Nano materials performance of TEG'S are tremendously increased which results in enhancement in the output voltage and power as well. The thermo-electric properties like Seebeck coefficient, thermal conductivity, thermal resistivity and figure of merit are important aspects in the designing of energy efficient generators. In the proposed work different thermo-electric generators are analyzed to give an appropriate solution for scavenging of thermal energy for powering of energy for self-powered devices.

METHODOLOGY

Measurement set-up:

The fig. 1. Shows experimental set-up for TEG, it utilize for the measurement of power and output voltage.

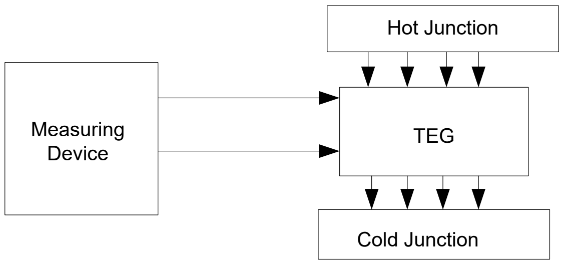


Figure 1. Experimental Set-Up for TEG.

Fabrication Process:

Thermocouples were formed on the polymide sheet by the lift-off process. AZ5214E photo resist was selected for this process. The slits of thermopile sheet of heat sink and absorber sheet were fabricated by excimer laser direct writing process. Cu film deposited on polymide film is used for the heat sink and absorber sheets in order to increase performance of heat conductivity. The thermopile sheet was formed into wavy form with the use of a holding fixture having a vacuum chuck on the top of wavy structure. After holding the thermocouple sheet on the wavy structure the heat sink and absorber sheets were bonded onto the thermophile sheet to form the CMOS process of Taiwan Semiconductor Manufacturing Company was utilized to fabricate the generator.

A). Thermocouples are connected in a series manner on a polymide sheet. Thermo-electric materials are- Ni and Cu, hot and cold junctions are formed by bending the thermopile sheet [1]. Fig. 2 shows basic structure of TEG. font size 10. Citation must be added as a number wherever necessary in square bract [1].

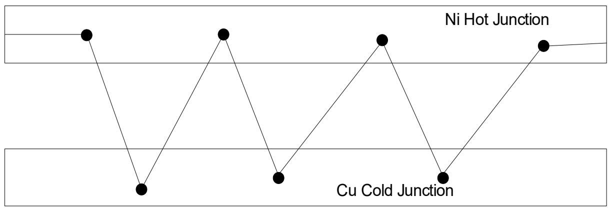


Figure 2. Basic structure of TEG.

A) CMOS TEG Design

220 thermocouples are connected in series. Phosphorus and Boron doped polysilicon is utilized to create a P - type & N-type semiconductor elements. Thermocouple is arranged on the top of the substrate. One junction of P-type & N-type polysilicon legs are coupled to the hot part of TEG & other junction to the cold part. Aluminum acts as a heat receiving area to conduct heat from the hot part to the cold part of TEG. Hot & cold part are isolated by trenches [2]. Fig. 3 shows CMOS TEG design.

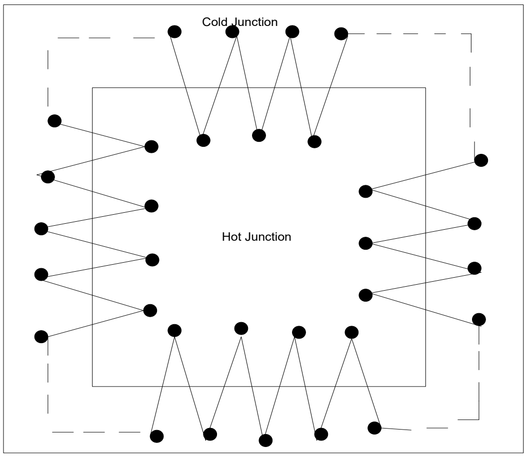


Figure 3. CMOS TEG design.

B) Schematic structure

The thermo-electric generator is constructed by 33 thermocouples in series. Each thermocouple is composed of N-type polysilicon strips. The junctions of p and n type strips are located on the suspended plate. This is the hottest part & other parts is the coldest part of the Silicon substrate [3]. Fig. 4 shows TEG schematic structure for N-type polysilicon strip.

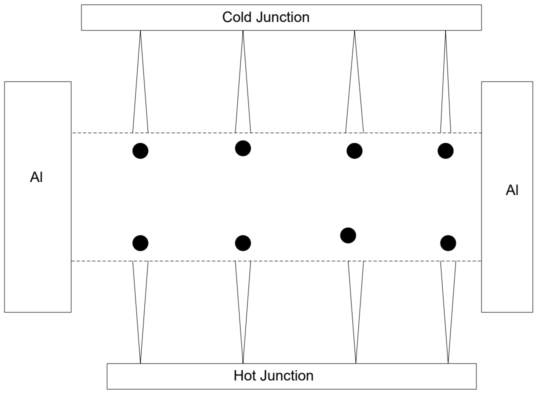
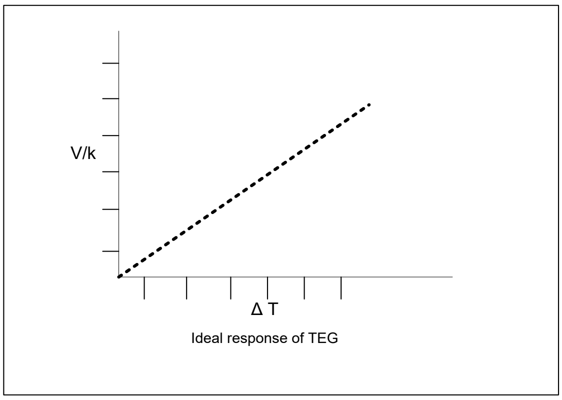


Figure 4. TEG design.

RESULTS AND DISCUSSION

i) In order to measure performance of the power generators FTGs are placed on a temperature control device. It was used to control arbitrary temperature between hot and cold junction. The output voltage measured with variations of temperature difference ($\Delta T=T_H-T_C$). Following figure shows relation between ΔT & output voltage.



The output voltage depends on the temperature difference between hot and cold junction.

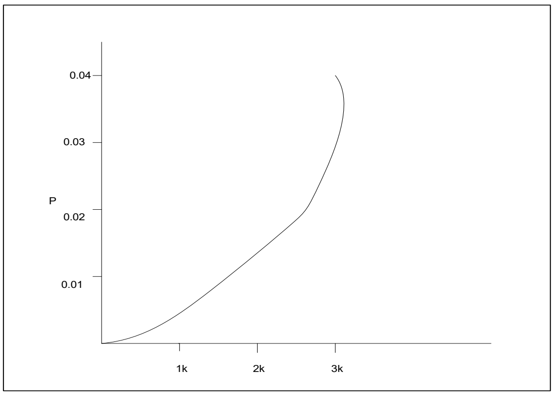


Fig. 5. Graph of o/p power Vs Temp Gradient

Table 1. Comparative study of Thermal Energy Generators (TEG)

Description	TEG1	TEG2	TEG3	TEG4
Material	polysilicon	Doped polysilicon	polysilicon	Quantum Wells
No. of Thermocouples	33	220	220	100000
Process	CMOS	CMOS	CMOS	CMOS
O/P Voltage	0.55 mV	0.28 mV	10.04 V/cm^2	--
O/P Power	1.1 µW	0.04 mW	100 µW	0.24 µW
Temp. Grad.	15k	3k	33k	1k

ii) Temperature difference between hot and cold junction is 3k. After thermal analysis of CMOS TEG output voltage and power can be calculated using theoretical models. Response of output power versus temperature difference is as follows.

iii) Performance of µTEG is characterized by 20^{0}C temp difference. Measurement shows that among the 10 thermocouples sizes 60 µm x 4 µm has the largest power factor. The power harvested is about 100 µW/cm^2. The thermal resistance of the single thermocouple is 3.3 x 10^{6}k/watt.

CONCLUSION

By the study of different TEG`s thermal energy harvesting is significantly appropriate for the various applications. In order to achieve higher o/p voltage and power thermo-electric material BiTe will be adopted. The power of devices can be enhanced using many generators in series. In addition, the power can be improved by structural design, by changing thermocouple material to increase temperature difference and Seebeck coefficient. TEG`s can be extended into an array in order to achieve higher power. Efficiency of thermoelectric material is described by the figure of merit (ZT).

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